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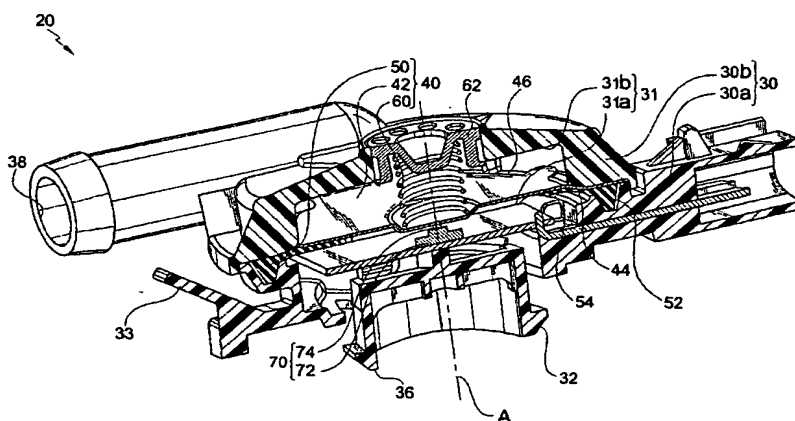
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- (71) Applicant: **SIEMENS VDO AUTOMOTIVE INC.**
[CA/CA]; 700 Park Avenue East, Chatham, Ontario N7M 5M7 (CA).
- (72) Inventors: **PERRY, Paul, D.**; 82 Gladstone Avenue, Chatham, Ontario N7L 2C3 (CA). **VEINOTTE, Andre**;
- (74) Agent: **MACRAE & CO.**; P.O. Box 806, Station B, Ottawa, Ontario K1P 5T4 (CA).
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(54) Title: FUEL SYSTEM INCLUDING AN APPARATUS AND A METHOD FOR FUEL VAPOR PRESSURE MANAGEMENT



(57) Abstract: A fuel system and method for supplying fuel to an internal combustion engine. The fuel system includes a fuel tank, an intake manifold, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus (20). The fuel vapor pressure management apparatus includes a housing (30), a pressure operable device (40), and a switch (70). The housing is coupled to the fuel vapor collection canister and defines an interior chamber (31). The pressure operable device separates the interior chamber into a first portion connected to canister, and a second portion connected to a vent port (38). The pressure operable device includes a poppet (52) and a seal (50) engaging the poppet. A first arrangement of the pressure operable device occurs when there is a first negative pressure level in the canister relative to the vent port, and the seal is in a first deformed configuration. A second arrangement permits a first fluid flow from the vent port to the canister when the seal is in a second deformed configuration. And a third arrangement permits a second fluid flow from the canister to the vent port when the seal is in an undeformed configuration.

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FUEL SYSTEM INCLUDING AN APPARATUS AND A METHOD FOR FUEL VAPOR PRESSURE MANAGEMENT

Cross Reference to Related Applications

[0001] This application claims the benefit of the earlier filing date of U.S. Provisional Application No. 60/298,255, filed 14 June 2001, U.S. Provisional Application No. 60/310,750, filed 8 August 2001, and the U.S. Provisional Application identified as Attorney Docket No. 051481-5093-PR, filed 30 May 2002, all of which are incorporated by reference herein in their entirety.

Field of the Invention

[0002] A fuel system that includes a fuel vapor pressure management apparatus and method that manages pressure and detects leaks in a fuel system. In particular, a volatile fuel system including a fuel vapor pressure management apparatus and method that uses naturally forming vacuum to perform a leak diagnostic for a headspace in a fuel tank, a canister that collects volatile fuel vapors from the headspace, a purge valve, and the associated pipes, conduits, hoses, and connections.

Background of the Invention

[0003] Conventional fuel systems for vehicles with internal combustion engines can include a canister that accumulates fuel vapor from a headspace of a fuel tank. If there is a leak in the fuel tank, the canister, or any other component of the fuel system, fuel vapor could escape through the leak and be released into the atmosphere instead of being accumulated in the canister. Various government regulatory agencies, e.g., the California Air Resources Board, have promulgated standards related to limiting fuel vapor releases into the atmosphere. Thus, it is believed that there is a need to avoid releasing fuel vapors into the atmosphere, and to provide an apparatus and a method for performing a leak diagnostic, so as to comply with these standards.

[0004] In such conventional fuel systems, excess fuel vapor can accumulate immediately after engine shutdown, thereby creating a positive pressure in the fuel vapor pressure management system. Excess negative pressure in closed fuel systems can occur under some operating and atmospheric conditions, thereby causing stress on components of these fuel systems. Thus, it is believed that there is a need to vent, or "blow-off," the positive pressure,

and to vent, or "relieve," the excess negative pressure. Similarly, it is also believed to be desirable to relieve excess positive pressure that can occur during tank refueling. Thus, it is believed that there is a need to allow air, but not fuel vapor, to exit the tank at high flow rates during tank refueling. This is commonly referred to as onboard refueling vapor recovery (ORVR).

Summary of the Invention

[0005] The present invention provides a fuel system for supplying fuel to an internal combustion engine. The fuel system includes a fuel tank that has a headspace, an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus. The fuel tank includes a headspace that is in fluid communication with the intake manifold, the fuel vapor collection canister, the purge valve, and the fuel vapor pressure management apparatus. The purge valve has a first side that is in fluid communication with the intake manifold and has a second side that is in fluid communication with fuel vapor collection canister and with the headspace. The fuel vapor pressure management apparatus includes a housing, a pressure operable device, and a switch. The housing is coupled to the fuel vapor collection canister and defines an interior chamber. The pressure operable device separates the interior chamber into a first portion that is in fluid communication with the fuel vapor collection canister, and a second portion that is in fluid communication with atmosphere via a filter. The pressure operable device includes a poppet that is movable along an axis, and a seal that is adapted to cooperatively engage the poppet. A first arrangement of the pressure operable device occurs when there is a first negative pressure level in the fuel vapor collection canister relative to the atmosphere, and the seal is in a first deformed configuration. A second arrangement of the pressure operable device permits a first fluid flow from the atmosphere, through a filter, to the fuel vapor collection canister when the seal is in a second deformed configuration. And a third arrangement of the pressure operable device permits a second fluid flow from the fuel vapor collection canister to the atmosphere, via a filter, when the seal is in an undeformed configuration. The switch signals the first arrangement of the pressure operable device.

[0006] The present invention also provides a fuel system for supplying fuel to an internal combustion engine. The fuel system includes a fuel tank that has a headspace, an intake

manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus. The fuel tank includes a headspace that is in fluid communication with the intake manifold, the fuel vapor collection canister, the purge valve, and the fuel vapor pressure management apparatus. The purge valve has a first side that is in fluid communication with the intake manifold and has a second side that is in fluid communication with fuel vapor collection canister and with the headspace. The fuel vapor pressure management apparatus includes a housing that defines an interior chamber, a pressure operable device that occupies a first space in the interior chamber, and a switch that occupies a second space in the interior chamber. The housing and the interior chamber occupying a volume less than 240 cubic centimeters. The pressure operable device performs a leak diagnostic based on a negative pressure at a first pressure level, relieves negative pressure below the first pressure level, and blows-off positive pressure above a second pressure level. The switch signals the negative pressure at the first pressure level.

[0007] The present invention also provides a method of using naturally forming vacuum to evaluate a fuel system supplying fuel to an internal combustion engine. The method includes providing a fuel tank including a headspace, coupling in fluid communication the headspace with an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, and detecting the vacuum that naturally forms in the headspace. The fuel vapor management apparatus includes a housing defining an interior chamber, excludes a diaphragm partitioning the interior chamber, and excludes an electromechanical actuator.

[0008] The present invention also provides a method of managing pressure in a fuel system supplying fuel to an internal combustion engine. The method includes providing a fuel tank including a headspace, connecting to the headspace an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, and relieving excess pressure that forms in the headspace. The fuel vapor management apparatus includes a housing defining an interior chamber, excludes a diaphragm partitioning the interior chamber, and excludes an electromechanical actuator.

[0009] The present invention also provides a method of managing pressure in a fuel system supplying fuel to an internal combustion engine. The method includes providing a fuel tank including a headspace, connecting to the headspace an intake manifold of the internal

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combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, detecting the vacuum that naturally forms in the headspace, and relieving excess pressure that forms in the headspace. The fuel vapor management apparatus includes a housing defining an interior chamber, excludes a diaphragm partitioning the interior chamber, and excludes an electromechanical actuator.

[0010] The present invention also provides a method of managing pressure in a fuel system supplying fuel to an internal combustion engine. The method includes providing a fuel tank including a headspace, connecting in fluid communication the headspace to a fuel vapor collection canister, connecting in fluid communication the fuel vapor collection canister to a fuel vapor pressure management apparatus, establishing a fluid flow path extending between the headspace in the fuel tank to atmosphere, relieving excess negative pressure with fluid flow in a first direction along the fluid flow path; and relieving excess positive pressure with fluid flow in a second direction along the fluid flow path. The fuel vapor pressure management apparatus performs leak detection on the headspace, performs excess negative pressure relief on the headspace, and performs excess positive pressure relief on the headspace. The fuel vapor management apparatus includes a housing defining an interior chamber and a pressure operable device. The housing includes first and second ports that communicate with the interior chamber. The pressure operable device separates the interior chamber into a first portion that is in fluid communication with the first port, and a second portion that is in fluid communication with the second port. The establishing the fluid flow path includes passing through the fuel vapor collection canister, passing through the first port, passing through the interior chamber, and passing through the second port. The second direction is opposite to the first direction.

[0011] The present invention also provides a method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine. The method includes coupling in fluid communication a headspace of the fuel system to a fuel vapor pressure management apparatus, coupling in electrical communication to the fuel vapor pressure management system an electrical control unit, supplying electrical current to the fuel vapor pressure management system and to the electrical control unit, and performing a leak detection test on the headspace. And the leak detection test draws no more than 100 milliamperes of the electrical current.

[0012] The present invention also provides a method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine. The method includes coupling in fluid communication a headspace of the fuel system to a fuel vapor pressure management apparatus, and performing with the fuel vapor pressure management apparatus a leak detection test on the headspace. The leak detection test occurs during a period of up to 90 minutes.

[0013] The present invention also provides a method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine. The method includes coupling in fluid communication a headspace of the fuel system to a fuel vapor pressure management apparatus, and performing with the fuel vapor pressure management apparatus a leak detection test on the headspace. The leak detection test occurs during a period of at least 20 minutes.

Brief Description of the Drawings

[0014] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate presently preferred embodiments of the invention, and, together with the general description given above and the detailed description given below, serve to explain features of the invention.

[0015] Figure 1 is a schematic illustration of a fuel system, in accordance with the detailed description of the preferred embodiment, which includes a fuel vapor pressure management apparatus.

[0016] Figure 2A is a first cross sectional view of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0017] Figure 2B are detail views of a seal for the fuel vapor pressure management apparatus shown in Figure 2A.

[0018] Figure 2C is a second cross sectional view of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0019] Figure 3A is a schematic illustration of a leak detection arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0020] Figure 3B is a schematic illustration of a vacuum relief arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0021] Figure 3C is a schematic illustration of a pressure blow-off arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0022] Figure 4 is a graph illustrating the time period required to detect leaks.

Detailed Description of the Preferred Embodiment

[0023] As it is used in this description, “atmosphere” generally refers to the gaseous envelope surrounding the Earth, and “atmospheric” generally refers to a characteristic of this envelope.

[0024] As it is used in this description, “pressure” is measured relative to the ambient atmospheric pressure. Thus, positive pressure refers to pressure greater than the ambient atmospheric pressure and negative pressure, or “vacuum,” refers to pressure less than the ambient atmospheric pressure.

[0025] Also, as it is used in this description, “headspace” refers to the variable volume within an enclosure, e.g. a fuel tank, that is above the surface of the liquid, e.g., fuel, in the enclosure. In the case of a fuel tank for volatile fuels, e.g., gasoline, vapors from the volatile fuel may be present in the headspace of the fuel tank.

[0026] Referring to Figure 1, a fuel system 10, e.g., for an engine (not shown), includes a fuel tank 12, a vacuum source 14 such as an intake manifold of the engine, a purge valve 16, a fuel vapor collection canister 18 (e.g., a charcoal canister), and a fuel vapor pressure management apparatus 20.

[0027] The fuel vapor pressure management apparatus 20 performs a plurality of functions including signaling 22 that a first predetermined pressure (vacuum) level exists, “vacuum relief” or relieving negative pressure 24 at a value below the first predetermined pressure level, and “pressure blow-off” or relieving positive pressure 26 above a second pressure level.

[0028] Other functions are also possible. For example, the fuel vapor pressure management apparatus 20 can be used as a vacuum regulator, and in connection with the operation of the purge valve 16 and an algorithm, can perform large leak detection on the fuel system 10. Such large leak detection could be used to evaluate situations such as when a refueling cap 12a is not replaced on the fuel tank 12.

[0029] It is understood that volatile liquid fuels, e.g., gasoline, can evaporate under certain conditions, e.g., rising ambient temperature, thereby generating fuel vapor. In the course of cooling that is experienced by the fuel system 10, e.g., after the engine is turned off, a vacuum is naturally created by cooling the fuel vapor and air, such as in the headspace of the fuel tank 12 and in the fuel vapor collection canister 18. According to the present description, the existence of a vacuum at the first predetermined pressure level indicates that the integrity of the fuel system 10 is satisfactory. Thus, signaling 22 is used to indicate the integrity of the fuel system 10, i.e., that there are no appreciable leaks. Subsequently, the vacuum relief 24 at a pressure level below the first predetermined pressure level can protect the fuel tank 12, e.g., can prevent structural distortion as a result of stress caused by vacuum in the fuel system 10.

[0030] After the engine is turned off, the pressure blow-off 26 allows excess pressure due to fuel evaporation to be vented, and thereby expedite the occurrence of vacuum generation that subsequently occurs during cooling. The pressure blow-off 26 allows air within the fuel system 10 to be released while fuel vapor is retained. Similarly, in the course of refueling the fuel tank 12, the pressure blow-off 26 allows air to exit the fuel tank 12 at a high rate of flow.

[0031] At least two advantages are achieved in accordance with a system including the fuel vapor pressure management apparatus 20. First, a leak detection diagnostic can be performed on fuel tanks of all sizes. This advantage is significant in that previous systems for detecting leaks were not effective with known large volume fuel tanks, e.g., 100 gallons or more. Second, the fuel vapor pressure management apparatus 20 is compatible with a number of different types of purge valves, including digital and proportional purge valves.

[0032] Figure 2A shows an embodiment of the fuel vapor pressure management apparatus 20 that is particularly suited to being mounted on the fuel vapor collection canister 18. The fuel vapor pressure management apparatus 20 includes a housing 30 that can be mounted to the body of the fuel vapor collection canister 18 by a "bayonet" style attachment 32. A seal (not shown) can be interposed between the fuel vapor collection canister 18 and the fuel vapor pressure management apparatus 20 so as to provide a fluid tight connection. The attachment 32, in combination with a snap finger 33, allows the fuel vapor pressure management apparatus 20 to be readily serviced in the field. Of course, different styles of attachments between the fuel vapor pressure management apparatus 20 and the body of the fuel vapor collection canister 18 can be substituted for the illustrated bayonet attachment 32. Examples

of different attachments include a threaded attachment, and an interlocking telescopic attachment. Alternatively, the fuel vapor collection canister 18 and the housing 30 can be bonded together (e.g., using an adhesive), or the body of the fuel vapor collection canister 18 and the housing 30 can be interconnected via an intermediate member such as a rigid pipe or a flexible hose.

[0033] The housing 30 defines an interior chamber 31 and can be an assembly of a first housing part 30a and a second housing part 30b. The first housing part 30a includes a first port 36 that provides fluid communication between the fuel vapor collection canister 18 and the interior chamber 31. The second housing part 30b includes a second port 38 that provides fluid communication, e.g., venting, between the interior chamber 31 and the ambient atmosphere. A filter (not shown) can be interposed between the second port 38 and the ambient atmosphere for reducing contaminants that could be drawn into the fuel vapor pressure management apparatus 20 during the vacuum relief 24 or during operation of the purge valve 16.

[0034] In general, it is desirable to minimize the number of housing parts to reduce the number of potential leak points, i.e., between housing pieces, which must be sealed.

[0035] An advantage of the fuel vapor pressure management apparatus 20 is its compact size. The volume occupied by the fuel vapor pressure management apparatus 20, including the interior chamber 31, is less than all other known leak detection devices, the smallest of which occupies more than 240 cubic centimeters. That is to say, the fuel vapor pressure management apparatus 20, from the first port 36 to the second port 38 and including the interior chamber 31, occupies less than 240 cubic centimeters. In particular, the fuel vapor pressure management apparatus 20 occupies a volume of less than 100 cubic centimeters. This size reduction over known leak detection devices is significant given the limited availability of space in contemporary automobiles.

[0036] A pressure operable device 40 can separate the interior chamber 31 into a first portion 31a and a second portion 31b. The first portion 31a is in fluid communication with the fuel vapor collection canister 18 through the first port 36, and the second portion 31b is in fluid communication with the ambient atmosphere through the second port 38.

[0037] The pressure operable device 40 includes a poppet 42, a seal 50, and a resilient element 60. During the signaling 22, the poppet 42 and the seal 50 cooperatively engage one

another to prevent fluid communication between the first and second ports 36,38. During the vacuum relief 24, the poppet 42 and the seal 50 cooperatively engage one another to permit restricted fluid flow from the second port 38 to the first port 36. During the pressure blow-off 26, the poppet 42 and the seal 50 disengage one another to permit substantially unrestricted fluid flow from the first port 36 to the second port 38.

[0038] The pressure operable device 40, with its different arrangements of the poppet 42 and the seal 50, may be considered to constitute a bi-directional check valve. That is to say, under a first set of conditions, the pressure operable device 40 permits fluid flow along a path in one direction, and under a second set of conditions, the same pressure operable device 40 permits fluid flow along the same path in the opposite direction. The volume of fluid flow during the pressure blow-off 26 may be three to ten times as great as the volume of fluid flow during the vacuum relief 24.

[0039] The pressure operable device 40 operates without an electromechanical actuator, such as a solenoid that is used in a known leak detection device to controllably displace a fluid flow control valve. Thus, the operation of the pressure operable device 40 can be controlled exclusively by the pressure differential between the first and second ports 36,38. Preferably, all operations of the pressure operable device 40 are controlled by fluid pressure signals that act on one side, i.e., the first port 36 side, of the pressure operable device 40.

[0040] The pressure operable device 40 also operates without a diaphragm. Such a diaphragm is used in the known leak detection device to sub-partition an interior chamber and to actuate the flow control valve. Thus, the pressure operable device 40 exclusively separates, and then only intermittently, the interior chamber 31. That is to say, there are at most two portions of the interior chamber 31 that are defined by the housing 30.

[0041] The poppet 42 is preferably a low density, substantially rigid disk through which fluid flow is prevented. The poppet 42 can be flat or formed with contours, e.g., to enhance rigidity or to facilitate interaction with other components of the pressure operable device 40.

[0042] The poppet 42 can have a generally circular form that includes alternating tabs 44 and recesses 46 around the perimeter of the poppet 42. The tabs 44 can center the poppet 42 within the second housing part 30b, and guide movement of the poppet 42 along an axis A. The recesses 46 can provide a fluid flow path around the poppet 42, e.g., during the vacuum relief 24 or during the pressure blow-off 26. A plurality of alternating tabs 44 and recesses 46

are illustrated, however, there could be any number of tabs 44 or recesses 46, including none, e.g., a disk having a circular perimeter. Of course, other forms and shapes may be used for the poppet 42.

[0043] The poppet 42 can be made of any metal (e.g., aluminum), polymer (e.g., nylon), or another material that is impervious to fuel vapor, is low density, is substantially rigid, and has a smooth surface finish. The poppet 42 can be manufactured by stamping, casting, or molding. Of course, other materials and manufacturing techniques may be used for the poppet 42.

[0044] The seal 50 can have an annular form including a bead 52 and a lip 54. The bead 52 can be secured between and seal the first housing part 30a with respect to the second housing part 30b. The lip 54 can project radially inward from the bead 52 and, in its undeformed configuration, i.e., as-molded or otherwise produced, project obliquely with respect to the axis A. Thus, preferably, the lip 54 has the form of a hollow frustum. The seal 50 can be made of any material that is sufficiently elastic to permit many cycles of flexing the seal 50 between undeformed and deformed configurations.

[0045] Preferably, the seal 50 is molded from rubber or a polymer, e.g., nitriles or fluorosilicones. More preferably, the seal has a stiffness of approximately 50 durometer (Shore A), and is self-lubricating or has an anti-friction coating, e.g., polytetrafluoroethylene.

[0046] Figure 2B shows an exemplary embodiment of the seal 50, including the relative proportions of the different features. Preferably, this exemplary embodiment of the seal 50 is made of Santoprene 123-40.

[0047] The resilient element 60 biases the poppet 42 toward the seal 50. The resilient element 60 can be a coil spring that is positioned between the poppet 42 and the second housing part 30b. Preferably, such a coil spring is centered about the axis A.

[0048] Different embodiments of the resilient element 60 can include more than one coil spring, a leaf spring, or an elastic block. The different embodiments can also include various materials, e.g., metals or polymers. And the resilient element 60 can be located differently, e.g., positioned between the first housing part 30a and the poppet 42.

[0049] It is also possible to use the weight of the poppet 42, in combination with the force of gravity, to urge the poppet 42 toward the seal 50. As such, the biasing force supplied by the resilient element 60 could be reduced or eliminated.

[0050] The resilient element 60 provides a biasing force that can be calibrated to set the value of the first predetermined pressure level. The construction of the resilient element 60, in particular the spring rate and length of the resilient member, can be provided so as to set the value of the second predetermined pressure level.

[0051] A switch 70 can perform the signaling 22. Preferably, movement of the poppet 42 along the axis A actuates the switch 70. The switch 70 can include a first contact fixed with respect to a body 72 and a movable contact 74. The body 72 can be fixed with respect to the housing 30, e.g., the first housing part 30a, and movement of the poppet 42 displaces movable contact 74 relative to the body 72, thereby closing or opening an electrical circuit in which the switch 70 is connected. In general, the switch 70 is selected so as to require a minimal actuation force, e.g., 50 grams or less, to displace the movable contact 74 relative to the body 72.

[0052] Different embodiments of the switch 70 can include magnetic proximity switches, piezoelectric contact sensors, or any other type of device capable of signaling that the poppet 42 has moved to a prescribed position or that the poppet 42 is exerting a prescribed force for actuating the switch 70.

[0053] Referring now to Figure 2C, there is shown an alternate embodiment of the fuel vapor pressure management apparatus 20'. As compared to Figure 2A, the fuel vapor pressure management apparatus 20' provides an alternative second housing part 30b' and an alternate poppet 42'. Otherwise, the same reference numbers are used to identify similar parts in the two embodiments of the fuel vapor pressure management apparatus 20 and 20'.

[0054] The second housing part 30b' includes a wall 300 projecting into the chamber 31 and surrounding the axis A. The poppet 42' includes at least one corrugation 420 that also surrounds the axis A. The wall 300 and the at least one corrugation 420 are sized and arranged with respect to one another such that the corrugation 420 telescopically receives the wall 300 as the poppet 42' moves along the axis A, i.e., to provide a dashpot type structure. Preferably, the wall 300 and the at least one corrugation 420 are right-circle cylinders.

[0055] The wall 300 and the at least one corrugation 420 cooperatively define a sub-chamber 310 within the chamber 31'. Movement of the poppet 42' along the axis A causes fluid displacement between the chamber 31' and the sub-chamber 310. This fluid displacement has the effect of damping resonance of the poppet 42'. A metering aperture (not

show) could be provided to define a dedicated flow channel for the displacement of fluid between the chamber 31' and the sub-chamber 310'.

[0056] As it is shown in Figure 2C, the poppet 42' can include additional corrugations that can enhance the rigidity of the poppet 42', particularly in the areas at the interfaces with the seal 50 and the resilient element 60.

[0057] The signaling 22 occurs when vacuum at the first predetermined pressure level is present at the first port 36. During the signaling 22, the poppet 42 and the seal 50 cooperatively engage one another to prevent fluid communication between the first and second ports 36,38.

[0058] The force created as a result of vacuum at the first port 36 causes the poppet 42 to be displaced toward the first housing part 30a. This displacement is opposed by elastic deformation of the seal 50. At the first predetermined pressure level, e.g., one inch of water vacuum relative to the atmospheric pressure, displacement of the poppet 42 will actuate the switch 70, thereby opening or closing an electrical circuit that can be monitored by an electronic control unit 76. As vacuum is released, the combination of the pressure at the first port 36 rising above the first predetermined pressure level, the elasticity of the seal 50, and any resilient return force built into the switch 70 all push the poppet 42 away from the switch 70, thereby resetting the switch 70.

[0059] During the signaling 22, there is a combination of forces that act on the poppet 42, i.e., the vacuum force at the first port 36 and the biasing force of the resilient element 60. This combination of forces moves the poppet 42 along the axis A to a position that deforms the seal 50 in a substantially symmetrical manner. This arrangement of the poppet 42 and seal 50 are schematically indicated in Figure 3A. In particular, the poppet 42 has been moved to its extreme position against the switch 70, and the lip 54 has been substantially uniformly pressed against the poppet 42 such that there is, preferably, annular contact between the lip 54 and the poppet 42.

[0060] In the course of the seal 50 being deformed during the signaling 22, the lip 54 slides along the poppet 42 and performs a cleaning function by scraping-off any debris that may be on the poppet 42.

[0061] The vacuum relief 24 occurs as the pressure at the first port 36 further decreases, i.e., the pressure decreases below the first predetermined pressure level that actuates the

switch 70. At some level of vacuum that is below the first predetermined level, e.g., six inches of water vacuum relative to atmosphere, the vacuum acting on the seal 50 will deform the lip 54 so as to at least partially disengage from the poppet 42.

[0062] During the vacuum relief 24, it is believed that, at least initially, the vacuum relief 24 causes the seal 50 to deform in an asymmetrical manner. This arrangement of the poppet 42 and seal 50 are schematically indicated in Figure 3B. A weakened section of the seal 50 could facilitate propagation of the deformation. In particular, as the pressure decreases below the first predetermined pressure level, the vacuum force acting on the seal 50 will, at least initially, cause a gap between the lip 54 and the poppet 42. That is to say, a portion of the lip 54 will disengage from the poppet 42 such that there will be a break in the annular contact between the lip 54 and the poppet 42, which was established during the signaling 22. The vacuum force acting on the seal 50 will be relieved as fluid, e.g., ambient air, flows from the atmosphere, through the second port 38, through the gap between the lip 54 and the poppet 42, through the first port 36, and into the canister 18.

[0063] The fluid flow that occurs during the vacuum relief 24 is restricted by the size of the gap between the lip 54 and the poppet 42. It is believed that the size of the gap between the lip 54 and the poppet 42 is related to the level of the pressure below the first predetermined pressure level. Thus, a small gap is all that is formed to relieve pressure slightly below the first predetermined pressure level, and a larger gap is formed to relieve pressure that is significantly below the first predetermined pressure level. This resizing of the gap is performed automatically by the seal 50 in accordance with the construction of the lip 54, and is believed to eliminate pulsations due to repeatedly disengaging and reengaging the seal 50 with respect to the poppet 42. Such pulsations could arise due to the vacuum force being relieved momentarily during disengagement, but then building back up as soon as the seal 50 is reengaged with the poppet 42.

[0064] Referring now to Figure 3C, the pressure blow-off 26 occurs when there is a positive pressure above a second predetermined pressure level at the first port 36. For example, the pressure blow-off 26 can occur when the tank 12 is being refueled. During the pressure blow-off 26, the poppet 42 is displaced against the biasing force of the resilient element 60 so as to space the poppet 42 from the lip 54. That is to say, the poppet 42 will completely separate from the lip 54 so as to eliminate the annular contact between the lip 54

and the poppet 42, which was established during the signaling 22. This separation of the poppet 42 from the seal 50 enables the lip 54 to assume an undeformed configuration, i.e., it returns to its "as-originally-manufactured" configuration. The pressure at the second predetermined pressure level will be relieved as fluid flows from the canister 18, through the first port 36, through the space between the lip 54 and the poppet 42, through the second port 38, and into the atmosphere.

[0065] The fluid flow that occurs during the pressure blow-off 26 is substantially unrestricted by the space between the poppet 42 and the lip 54. That is to say, the space between the poppet 42 and the lip 54 presents very little restriction to the fluid flow between the first and second ports 36,38.

[0066] At least four advantages are achieved in accordance with the operations performed by the fuel vapor pressure management apparatus 20. First, the signaling 22 provides a leak detection diagnostic using vacuum monitoring during natural cooling, e.g., after the engine is turned off. Second, the vacuum relief 24 provides negative pressure relief below the first predetermined pressure level, and the pressure blow-off 26 provides positive pressure relief above the second predetermined pressure level. Third, the vacuum relief 24 provides fail-safe purging of the fuel vapor collection canister 18 and the headspace. And fourth, the pressure blow-off 26 regulates the pressure in the fuel tank 12 during any situation in which the engine is turned off, thereby limiting the amount of positive pressure in the fuel tank 12 and allowing the cool-down vacuum effect to occur sooner.

[0067] Referring now to Figure 4, a plot 200 illustrating the frequency that closures of the switch 70 occur within a given period of time after an engine is turned off. The plot 200 shows that a minority of switch closures occur within the first 20 minutes after the engine is turned off, and that a majority of switch closures occur within 90 minutes after the engine is shut down. Thus, a leak detection test that is terminated within 20 minutes after the engine is turned off will not successfully detect a majority of the occurrences when a test would indicate that there are no appreciable leaks in the fuel system 10. That is to say, terminating a leak detection test within 20 minutes will result in a number of false indications that the fuel system 10 has an appreciable leak.

[0068] One reason for terminating a leak detection test within 20 minutes is that the current draw required to perform the test results in an unacceptable drain on the battery (not

shown) used to start an associated internal combustion engine (not shown). Such an unacceptable drain occurs after the engine is turned off, and could therefore adversely affect the ability to restart the engine. The leak detection test that is performed by the fuel vapor pressure management apparatus 20, in cooperation with the electronic control unit 76, draws less than 100 milliamperes of current from the battery, which does not result in an unacceptable drain on the battery and allows the fuel vapor pressure management apparatus 20 to perform leak detection tests over periods exceeding 20 minutes. The low current draw of the fuel vapor pressure management apparatus 20 can be attributable to eliminating pumps required to pressurize (positively or negatively) the fuel system 10, and to eliminating electromechanical actuators for mechanically displacing fluid flow control elements.

[0069] While the present invention has been disclosed with reference to certain preferred embodiments, numerous modifications, alterations, and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims, and equivalents thereof.

What is claimed is:

1. A fuel system for supplying fuel to an internal combustion engine, the fuel system comprising:
 - a fuel tank having a headspace;
 - an intake manifold of the internal combustion engine in fluid communication with the headspace;
 - a fuel vapor collection canister in fluid communication with the headspace;
 - a purge valve having a first side in fluid communication with the intake manifold and having a second side in fluid communication with fuel vapor collection canister and with the headspace; and
 - a fuel vapor pressure management apparatus including:
 - a housing coupled to the fuel vapor collection canister and defining an interior chamber;
 - a pressure operable device separating the interior chamber into a first portion in fluid communication with the fuel vapor collection canister and a second portion in fluid communication with a vent port, the pressure operable device including a poppet movable along an axis and a seal adapted to cooperatively engage the poppet, a first arrangement of the pressure operable device occurs when there is a first negative pressure level in the fuel vapor collection canister relative to the vent port and the seal is in a first deformed configuration, a second arrangement of the pressure operable device permits a first fluid flow from the vent port to the fuel vapor collection canister when the seal is in a second deformed configuration, and a third arrangement of the pressure operable device permits a second fluid flow from the fuel vapor collection canister to the vent port when the seal is in an undeformed configuration; and
 - a switch signaling the first arrangement of the pressure operable device.

2. The fuel system according to claim 1, wherein the poppet is movable along the axis between a first position, a second position, and an intermediate position between the first and second positions.
3. The fuel system according to claim 2, wherein the first and second arrangements of the pressure operable device comprise the poppet in the second position, and the third arrangement of the pressure operable device comprises the poppet in the first position.
4. The fuel system according to claim 2, further comprising:
a fourth arrangement of the pressure operable device prevents fluid communication between the fuel vapor collection canister to the vent port, and fourth arrangement comprises the poppet in the intermediate position and the seal in the first deformed configuration.
5. The fuel system according to claim 4, wherein the switch does not signal the fourth arrangement of the pressure operable device.
6. The fuel system according to claim 2, wherein the pressure operable device comprises:
a spring biasing the poppet toward the second position.
7. The fuel system according to claim 6, wherein a positive pressure above the first pressure level displaces the poppet against the biasing of the spring to the first position.
8. The fuel system according to claim 1, wherein the first arrangement of the pressure operable device prevents fluid communication between the fuel vapor collection canister and the vent port.
9. The fuel system according to claim 1, wherein the poppet is substantially rigid and the seal is relatively flexible with respect to the poppet.
10. The fuel vapor pressure management apparatus according to claim 1, wherein the first deformed configuration comprises a substantially symmetrical deformation of the seal, and the second deformed configuration comprises a generally asymmetrical deformation of the seal.
11. The fuel system according to claim 1, wherein the housing defines an aperture through which the fuel vapor collection canister and the vent port communicate in the second and third

arrangements, and the seal engages the poppet to occlude the aperture in the first arrangement.

12. The fuel system according to claim 1, further comprising:
 - an engine control unit operatively connected to the purge valve; and
 - a plurality of electrical connections adapted to electrically interconnect the switch with the engine control unit.
13. The fuel system according to claim 12, further comprising:
 - a control circuit disposed in the housing and electrically interconnecting the switch and the plurality of electrical connections.
14. The fuel system according to claim 1, further comprising:
 - a contiguous connection between the fuel vapor collection canister and the housing.
15. The fuel system according to claim 14, wherein the contiguous connection is selected from a group consisting of a bayonet connection, a threaded connection, and an interlocking sliding connection.
16. The fuel system according to claim 1, further comprising:
 - a remote connection extending between the fuel vapor collection canister and the housing spaced from the fuel vapor collection canister.
17. The fuel system according to claim 16, wherein the remote connection is selected from a group consisting of a rigid pipe and a flexible pipe.
18. A fuel system for supplying fuel to an internal combustion engine, the fuel system comprising:
 - a fuel tank having a headspace;
 - an intake manifold of the internal combustion engine in fluid communication with the headspace;
 - a fuel vapor collection canister in fluid communication with the headspace;

a purge valve having a first side in fluid communication with the intake manifold and having a second side in fluid communication with fuel vapor collection canister and with the headspace; and

a fuel vapor pressure management apparatus including:

a housing defining an interior chamber, the housing and the interior chamber occupying a volume less than 240 cubic centimeters; and

a pressure operable device occupying a first space in the interior chamber, the pressure operable device performing a leak diagnostic based on a negative pressure at a first pressure level, the pressure operable device relieving negative pressure below the first pressure level, and the pressure operable device blowing-off positive pressure above a second pressure level; and

a switch occupying a second space in the interior chamber, the switch signaling the negative pressure at the first pressure level.

19. The fuel system according to claim 18, wherein the housing and the interior chamber occupy a volume less than 100 cubic centimeters.
20. The fuel system according to claim 18, wherein the fuel vapor pressure management apparatus excludes an electromechanical actuator.
21. The fuel system according to claim 18, wherein the fuel vapor pressure management apparatus excludes a diaphragm partitioning the interior chamber.
22. A method of using naturally forming vacuum to evaluate a fuel system supplying fuel to an internal combustion engine, the method comprising:
 - providing a fuel tank including a headspace;
 - coupling in fluid communication the headspace with an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, the fuel vapor management apparatus:
 - including a housing defining an interior chamber;
 - excluding a diaphragm partitioning the interior chamber; and
 - excluding an electromechanical actuator; and
 - detecting the vacuum that naturally forms in the headspace.

23. The method according to claim 22, wherein the coupling comprises connecting the fuel tank to the intake manifold via the purge valve.
24. The method according to claim 22, wherein the coupling comprises connecting the fuel vapor collection canister to the intake manifold via the purge valve.
25. The method according to claim 22, wherein the coupling comprises connecting the fuel vapor pressure management apparatus to the intake manifold via the fuel vapor collection canister and the purge valve.
26. The method according to claim 25, wherein the coupling comprises connecting the fuel vapor pressure management apparatus between the fuel vapor collection canister and atmosphere.
27. The method according to claim 22, wherein the detecting comprises sensing a negative pressure level relative to atmosphere in the fuel vapor collection canister.
28. The method according to claim 27, wherein the negative pressure level is approximately negative one inch water relative to atmosphere.
29. The method according to claim 22, wherein the fuel vapor management apparatus comprises a housing and a pressure operable device, the housing defines an interior chamber and includes first and second ports communicating with the interior chamber, and the pressure operable device separates the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with a second port, the pressure operable device includes a poppet movable along an axis and a seal adapted to cooperatively engage the poppet, and the detecting occurs when there is a first negative pressure level at the first port relative to the second port and the seal is in a symmetrically deformed configuration.
30. A method of managing pressure in a fuel system supplying fuel to an internal combustion engine, the method comprising:
providing a fuel tank including a headspace;

connecting to the headspace an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, the fuel vapor management apparatus:

including a housing defining an interior chamber;
excluding a diaphragm partitioning the interior chamber; and
excluding an electromechanical actuator; and

relieving excess pressure that forms in the headspace.

31. The method according to claim 30, wherein the relieving excess pressure comprises relieving negative pressure below a negative pressure level relative to atmosphere.
32. The method according to claim 31, wherein the fuel vapor management apparatus senses the negative pressure level.
33. The method according to claim 32, wherein the negative pressure level occurs in the fuel vapor collection canister.
34. The method according to claim 30, wherein the relieving excess pressure comprises relieving positive pressure above a positive pressure level relative to atmosphere.
35. The method according to claim 34, wherein the fuel vapor management apparatus senses the positive pressure level.
36. The method according to claim 35, wherein the positive pressure level occurs in the fuel vapor collection canister.
37. The method according to claim 30, wherein the relieving excess pressure comprises relieving negative pressure below a negative pressure level relative to atmosphere and relieving positive pressure above a positive pressure level relative to atmosphere.
38. The method according to claim 37, wherein the fuel vapor management apparatus comprises a housing and a pressure operable device, the housing defines an interior chamber and includes first and second ports communicating with the interior chamber, and the pressure operable device separates the interior chamber into a first portion in fluid communication with

the first port and a second portion in fluid communication with a second port, the pressure operable device includes a poppet movable along an axis and a seal adapted to cooperatively engage the poppet, and the relieving negative pressure occurs when the pressure operable device permits a first fluid flow from the second port to the first port and when the seal is in an asymmetrically deformed configuration, and the relieving positive pressure occurs when the pressure operable device permits a second fluid flow from the first port to the second port and when the seal is in an undeformed configuration.

39. A method of managing pressure and using naturally forming vacuum to evaluate a fuel system supplying fuel to an internal combustion engine, the method comprising:

providing a fuel tank including a headspace;

coupling in fluid communication the headspace with an intake manifold of the internal combustion engine, a fuel vapor collection canister, a purge valve, and a fuel vapor pressure management apparatus, the fuel vapor management apparatus:

including a housing defining an interior chamber;

excluding a diaphragm partitioning the interior chamber; and

excluding an electromechanical actuator;

detecting the vacuum that naturally forms in the headspace; and

relieving excess pressure that forms in the headspace.

40. The method according to claim 39, wherein the detecting comprises sensing a negative pressure level relative to atmosphere in the fuel vapor collection canister, the relieving excess pressure comprises relieving negative pressure below the negative pressure level, and the relieving positive pressure above a positive pressure level relative to atmosphere.

41. The method according to claim 40, wherein the fuel vapor management apparatus comprises a housing and a pressure operable device, the housing defines an interior chamber and includes first and second ports communicating with the interior chamber, and the pressure operable device separates the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with a second port, the pressure operable device includes a poppet movable along an axis and a seal adapted to cooperatively engage the poppet, the detecting occurs when there is a first negative pressure level at the first

port relative to the second port and the seal is in a symmetrically deformed configuration, the relieving negative pressure occurs when the pressure operable device permits a first fluid flow from the second port to the first port and when the seal is in an asymmetrically deformed configuration, and the relieving positive pressure occurs when the pressure operable device permits a second fluid flow from the first port to the second port and when the seal is in an undeformed configuration.

42. A method of managing pressure in a fuel system supplying fuel to an internal combustion engine, the method comprising:

- providing a fuel tank including a headspace;

- connecting in fluid communication the headspace to a fuel vapor collection canister;

- connecting in fluid communication the fuel vapor collection canister to a fuel vapor pressure management apparatus, the fuel vapor pressure management apparatus performing leak detection on the headspace, performing excess negative pressure relief on the headspace, and performing excess positive pressure relief on the headspace, the fuel vapor management apparatus including:

 - a housing defining an interior chamber, the housing including first and second ports communicating with the interior chamber;

 - a pressure operable device separating the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with the second port; and

- establishing a fluid flow path extending between the headspace in the fuel tank to atmosphere, the establishing including passing through the fuel vapor collection canister, passing through the first port, passing through the interior chamber, and passing through the second port;

- relieving excess negative pressure with fluid flow in a first direction along the fluid flow path; and

- relieving excess positive pressure with fluid flow in a second direction along the fluid flow path, the second direction being opposite to the first direction.

43. The method according to claim 42, wherein the pressure operable device includes a poppet movable along an axis and an annular seal adapted to cooperatively engage the poppet.

44. The method according to claim 43, wherein the establishing includes passing around the poppet and passing through the annular seal.
45. A method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine, the method comprising:
coupling in fluid communication to a headspace of the fuel system a fuel vapor pressure management apparatus;
coupling in electrical communication to the fuel vapor pressure management system an electrical control unit;
supplying electrical current to the fuel vapor pressure management system and to the electrical control unit; and
performing a leak detection test on the headspace, the leak detection test drawing no more than 100 milliamperes of the electrical current.
46. A method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine, the method comprising:
coupling in fluid communication to a headspace of the fuel system a fuel vapor pressure management apparatus;
performing with the fuel vapor pressure management apparatus a leak detection test on the headspace, the leak detection test occurring during a period of up to 90 minutes.
47. The method according to claim 46, wherein the period of the leak detection test is at least 20 minutes.
48. A method of using naturally forming vacuum to detect leaks in a fuel system supplying fuel to an internal combustion engine, the method comprising:
coupling in fluid communication to a headspace of the fuel system a fuel vapor pressure management apparatus;
performing with the fuel vapor pressure management apparatus a leak detection test on the headspace, the leak detection test occurring during a period of at least 20 minutes.

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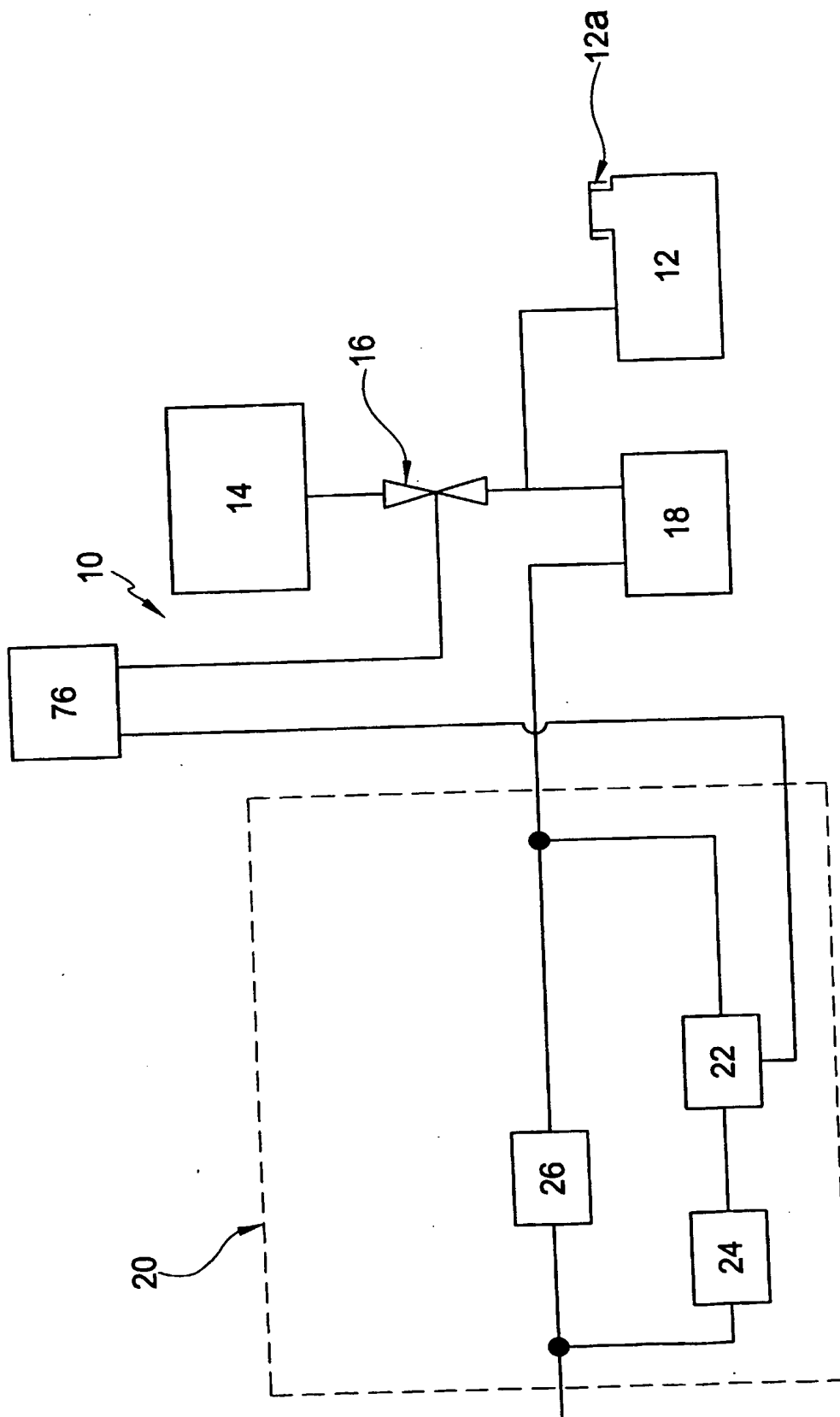


FIG.1

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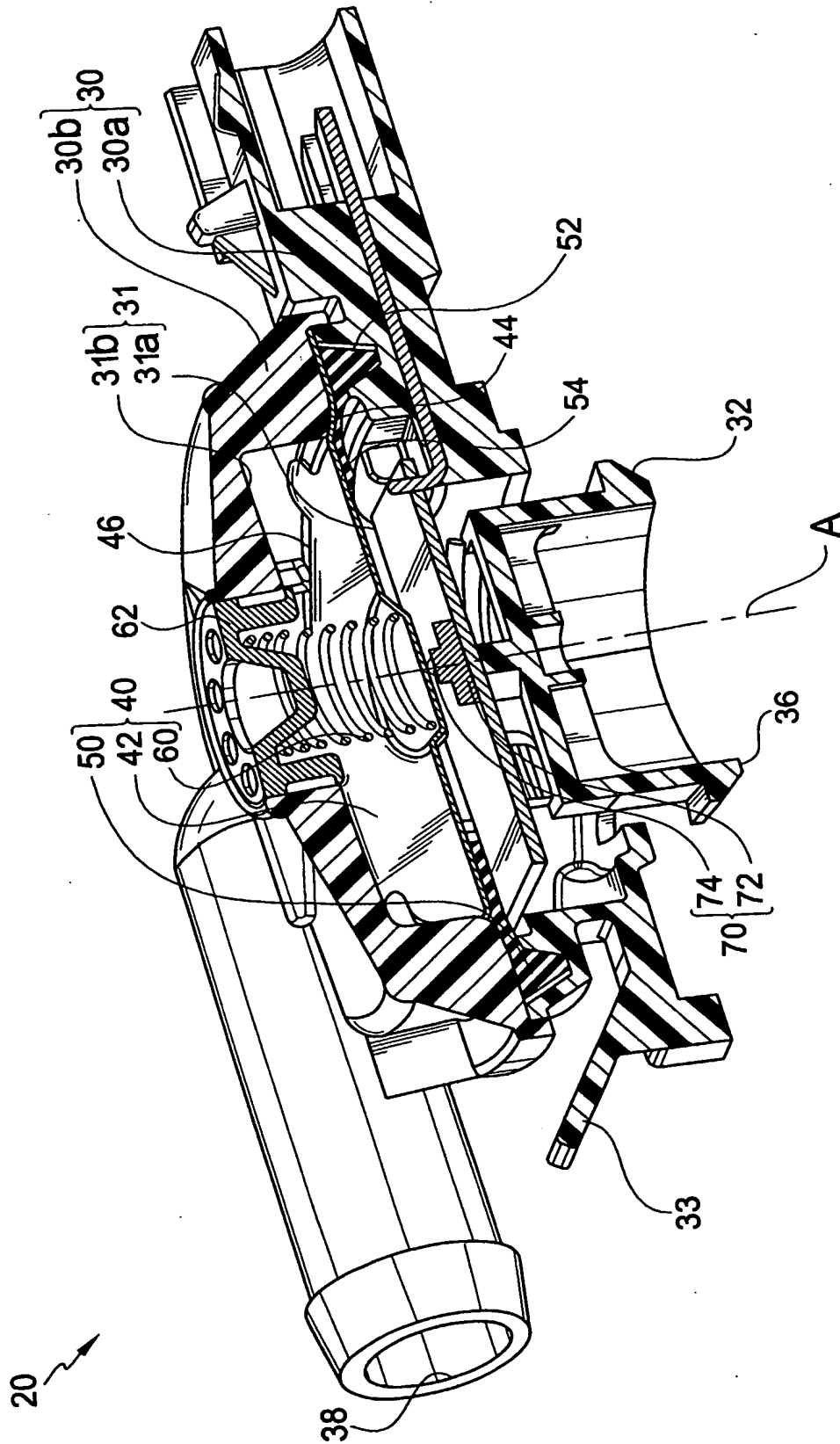
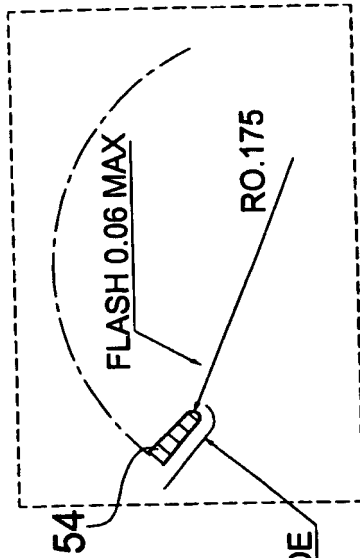
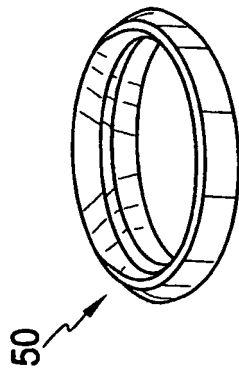


FIG. 2A

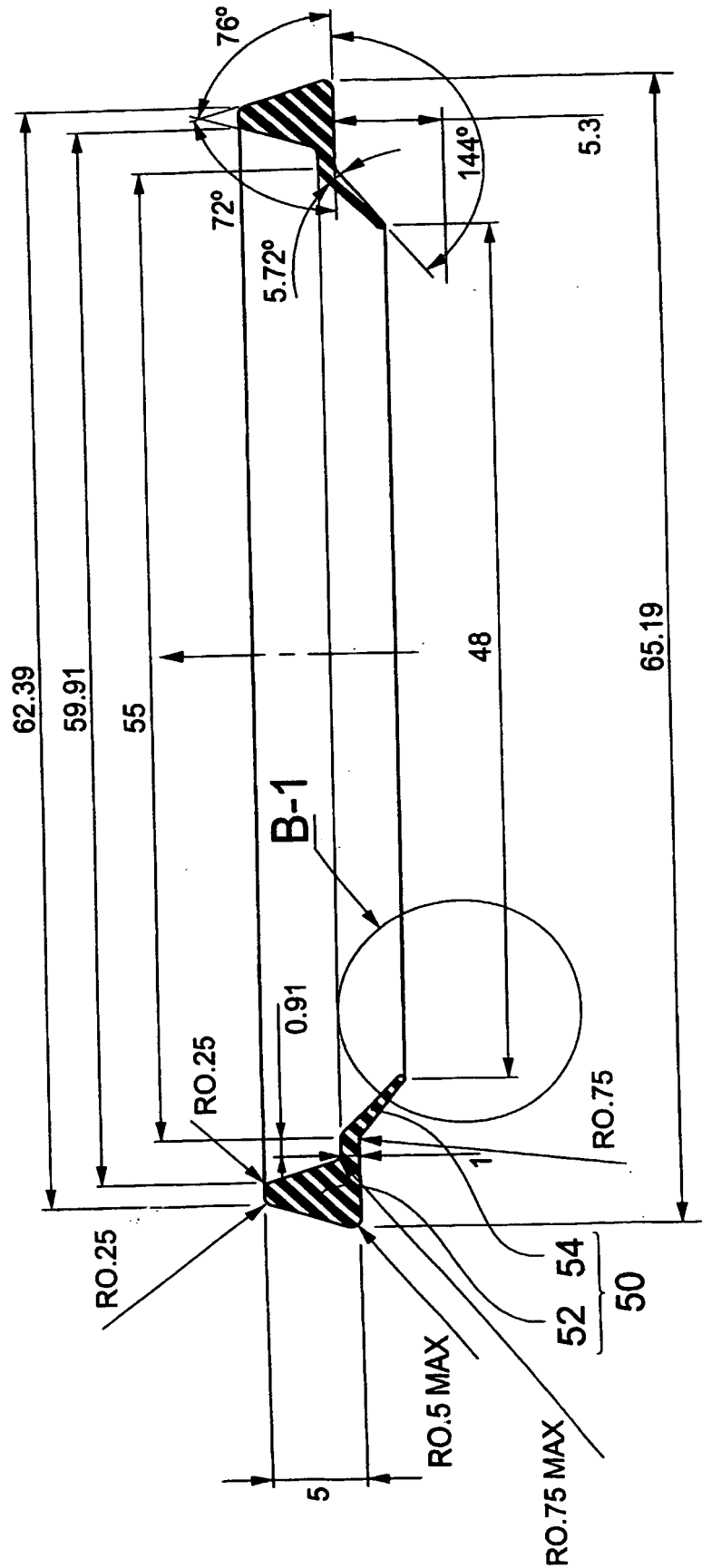
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FIG. 2B



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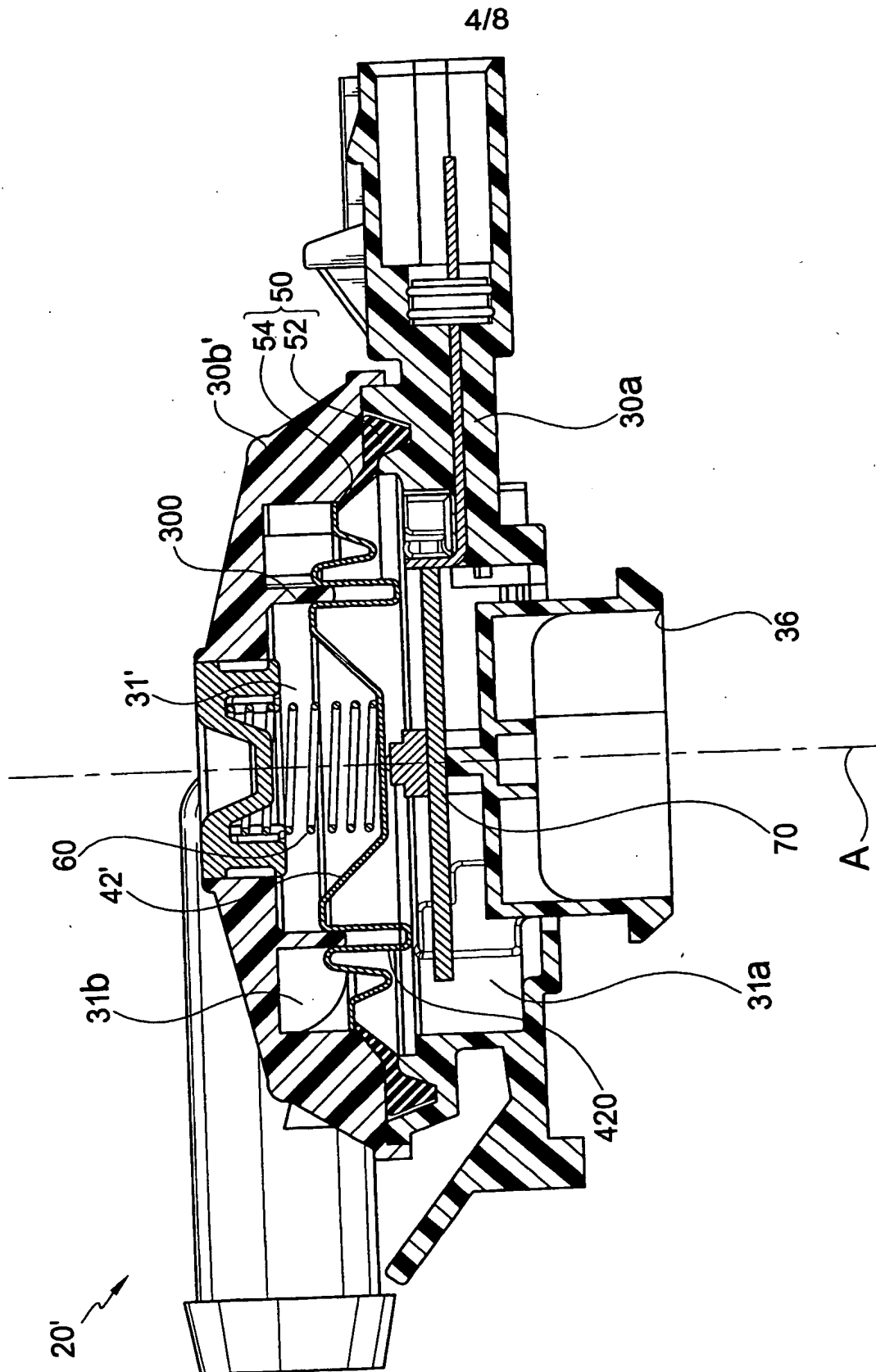


FIG. 2C

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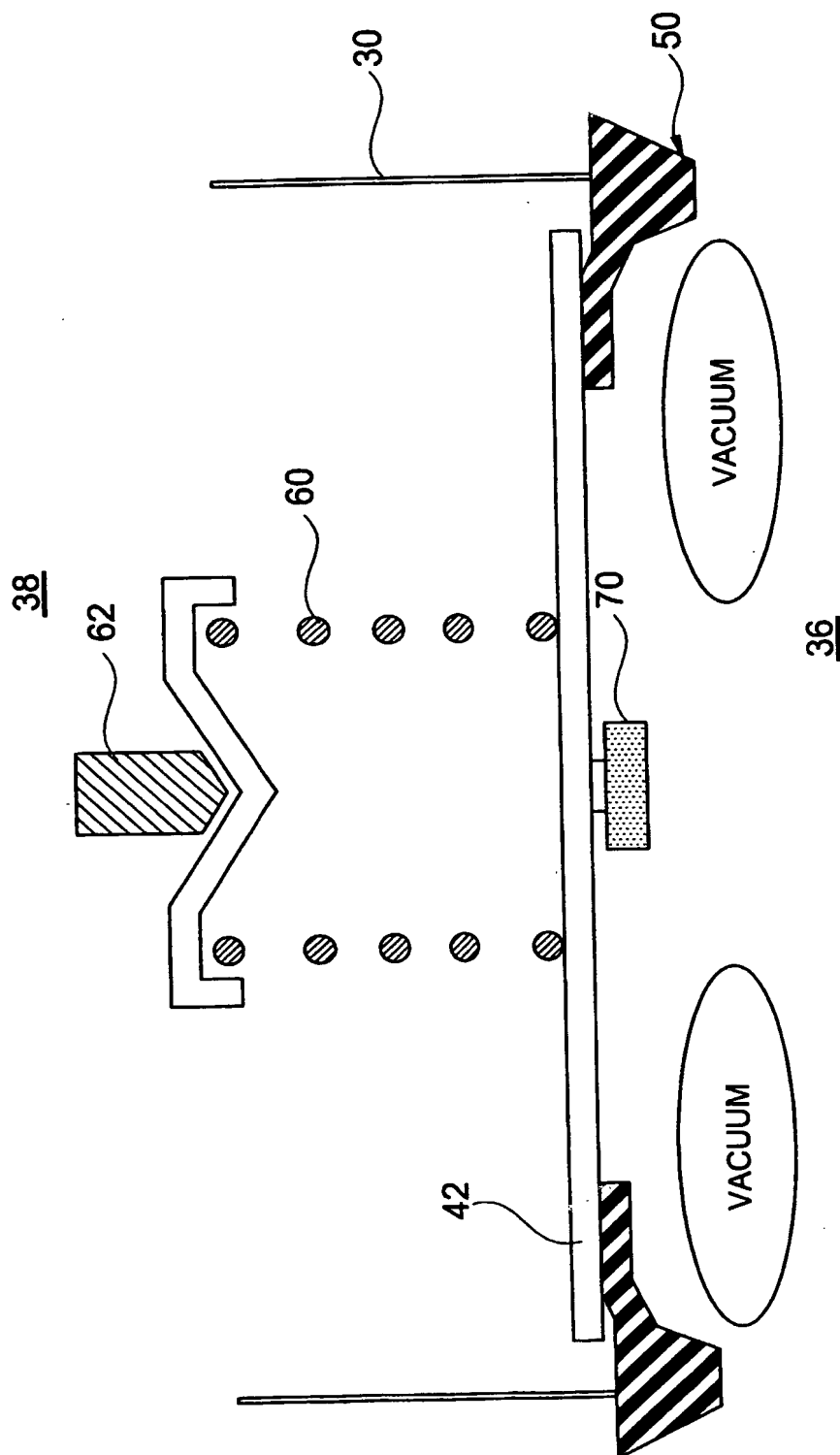


FIG. 3A

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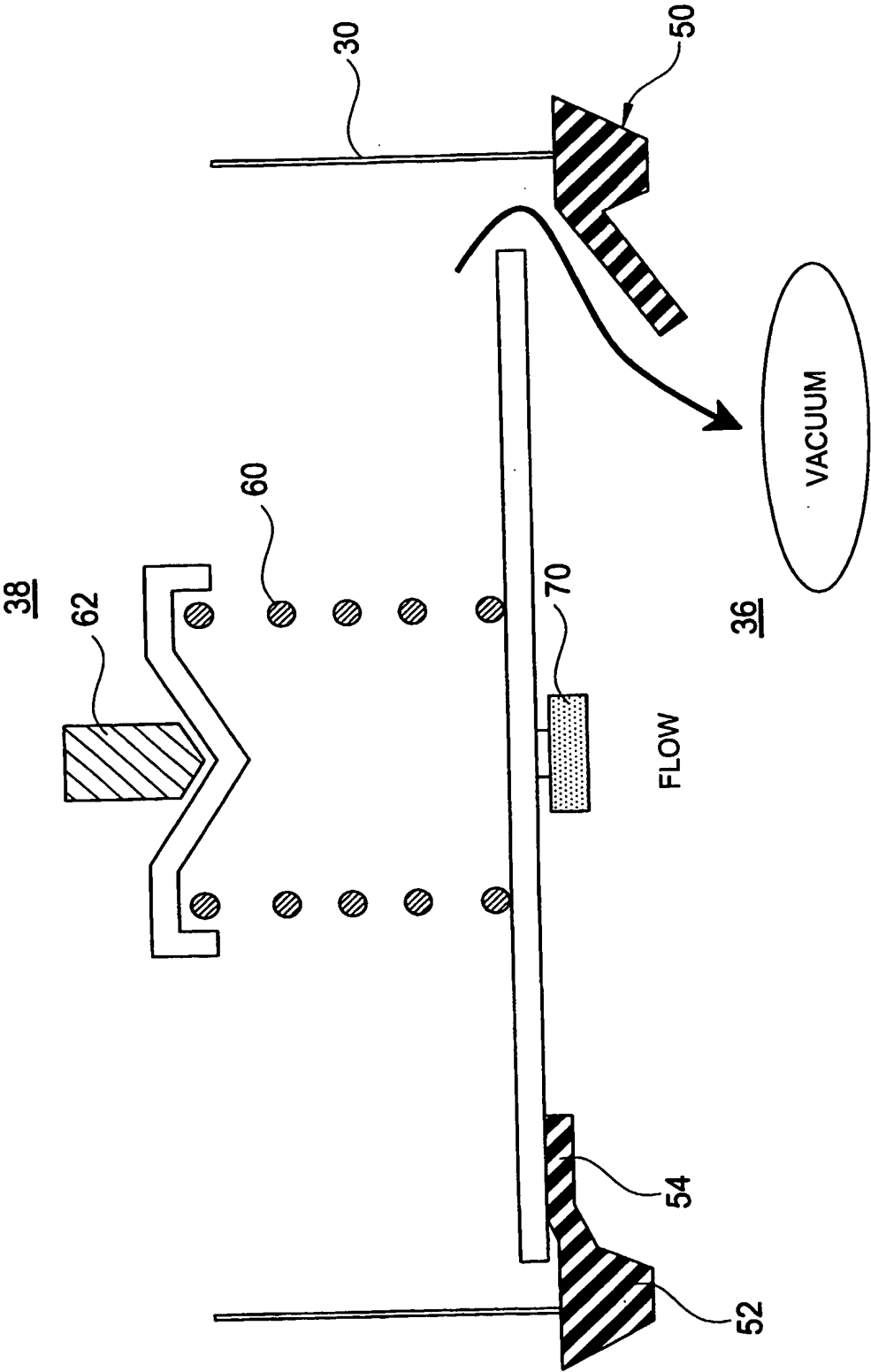


FIG.3B

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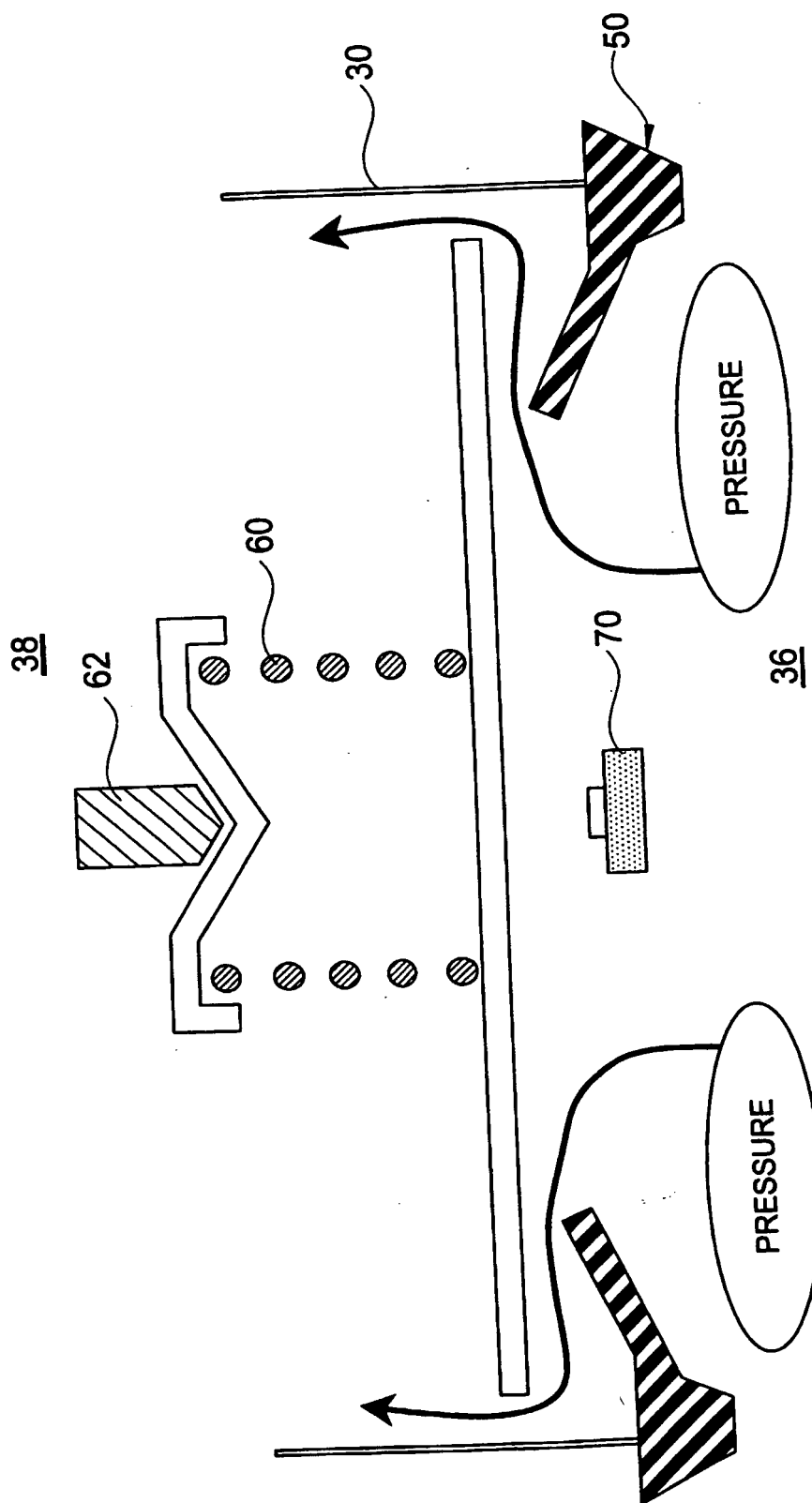


FIG.3C

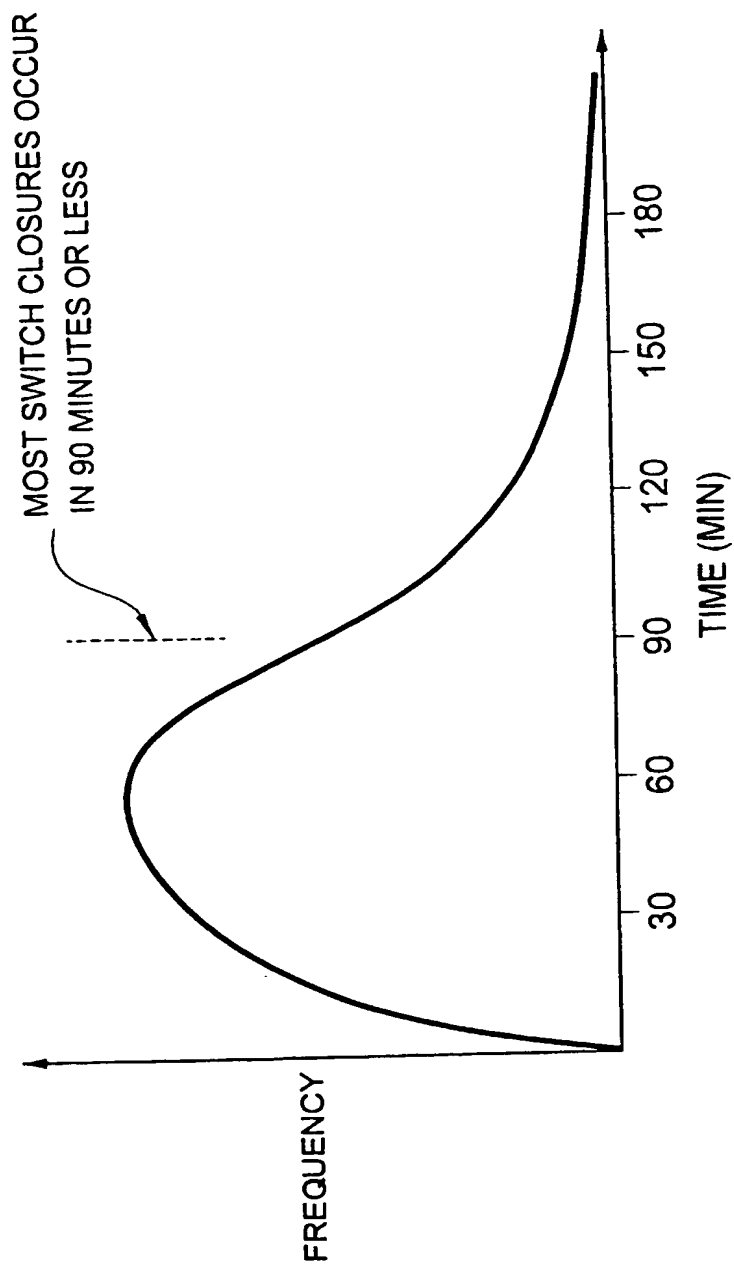


FIG.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 02/00901

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 F02M25/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 F02M F16K B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 01 38716 A (SIEMENS CANADA LTD)	18, 19,
Y	31 May 2001 (2001-05-31)	42-48
A	abstract; figures	1-3, 6-9,
	page 2, last paragraph -page 5, paragraph 3	11-17
	---	4, 5, 10,
Y	US 3 741 232 A (SOBERSKI GEORGE A)	20-41
A	26 June 1973 (1973-06-26)	1-3, 6-9,
	figures	11-17
	column 2, line 37 -column 5, line 18	4, 5, 10,
	---	18-48
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

16 October 2002

Date of mailing of the international search report

24/10/2002

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Döring, M

INTERNATIONAL SEARCH REPORT

Intern al Application No

PCT/CA 02/00901

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>US 5 524 662 A (BENJEY ROBERT P ET AL) 11 June 1996 (1996-06-11)</p> <p>abstract; figures column 3, line 18 - line 44 column 5, line 1 -column 6, line 17 -----</p>	<p>1,18,22, 30,39, 42,45, 46,48</p>

INTERNATIONAL SEARCH REPORT

Information on patent family members

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			WO 0138716 A1	31-05-2001
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